Chapter 5
Foundation and Abutment Preparation

5-1. Preparation

a. Earth foundations.

(1) The design of dams on earth foundations is based on the in situ shear strength of the foundation soils. For weak foundations, use of stage construction, foundation strengthening, or excavation of undesirable material may be more economical than using flat slopes or stability berms.

(2) Foundation preparation usually consists of clearing, grubbing to remove stumps and large roots in approximately the top 3 ft, and stripping to remove sod, topsoil, boulders, organic materials, rubbish fills, and other undesirable materials. It is not generally necessary to remove organic-stained soils. Highly compressible soils occurring in a thin surface layer or in isolated pockets should be removed.

(3) After stripping, the foundation surface will be in a loose condition and should be compacted. However, if a silty or clayey foundation soil has a high water content and high degree of saturation, attempts to compact the surface with heavy sheepsfoot or rubber-tired rollers will only remold the soil and disturb it, and only lightweight compaction equipment should be used. Where possible without disturbing the foundation soils, traffic over the foundation surface by the heaviest rollers or other construction equipment available is desirable to reveal compressible material that may have been overlooked in the stripping, such as pockets of soft material buried beneath a shallow cover. Stump holes should be filled and compacted by power-driven hand tampers.

(4) For dams on impervious earth foundations not requiring a cutoff, an inspection trench having a minimum depth of 6 ft should be made. This will permit inspection for abandoned pipes, soft pockets, tile fields, pervious zones, or other undesirable features not discovered by earlier exploration.

(5) Differential settlement of an embankment may lead to tension zones along the upper portion of the dam and to possible cracking along the longitudinal axis in the vicinity of steep abutment slopes at tie-ins or closure sections, or where thick deposits of unsuitable foundation soils have been removed (since in the latter case, the compacted fill may have different compressibility characteristics than adjacent foundation soils). Differential settlements along the dam axis may result in transverse cracks in the embankment which can lead to undesirable seepage conditions. To minimize this possibility, steep abutment slopes and foundation excavation slopes should be flattened, if feasible, particularly beneath the impervious zone of the embankment. This may be economically possible with earth abutments only. The portion of the abutment surface beneath the impervious zone should not slope steeply upstream or downstream, as such a surface might provide a plane of weakness.

(6) The treatment of an earth foundation under a rock-fill dam should be substantially the same as that for an earth dam. The surface layer of the foundation beneath the downstream rock-fill section must meet filter gradation criteria, or a filter layer must be provided, so that seepage from the foundation does not carry foundation material into the rock fill.

b. Rock foundations.

(1) Rock foundations should be cleaned of all loose fragments, including semidetached surface blocks of rock spanning relatively open crevices. Projecting knobs of rock should be removed to facilitate operation of compaction equipment and to avoid differential settlement. Cracks, joints, and openings beneath the core and possibly elsewhere (see below) should be filled with mortar or lean concrete according to the width of opening. The treatment of rock defects should not result in layers of grout or gunite that cover surface areas of sound rock, since they might crack under fill placement and compaction operations.

(2) The excavation of shallow exploration or core trenches by blasting may damage the rock. Where this may occur, exploration trenches are not recommended, unless they can be excavated without blasting. Where core trenches disclose cavities, large cracks, and joints, the core trench should be backfilled with concrete to prevent possible erosion of core materials by water seeping through joints or other openings in the rock.

(3) Shale foundations should not be permitted to dry out before placing embankment fill, nor should they be permitted to swell prior to fill placement. Consequently, it is desirable to defer removal of the last few feet of shale until just before embankment fill placement begins.

(4) Where an earth dam is constructed on a jointed rock foundation, it is essential to prevent embankment fill from entering joints or other openings in the rock. This

can be done in the core zone by extending the zone into sound rock and by treating the rock as discussed above. Where movement of shell materials into openings in the rock foundation is possible, joints and other openings should be filled, as discussed, beneath both upstream and downstream shells. An alternative is to provide filter layers between the foundation and the shells of the dam. Such treatment will generally not be necessary beneath shells of rock-fill dams.

(5) Limestone rock foundation may contain solution cavities and require detailed investigations, special observations when making borings (see EM 1110-1-1804), and careful study of aerial photographs, combined with surface reconnaissance to establish if surface sinks are present. However, the absence of surface sinks cannot be accepted as proof that a foundation does not contain solution features. The need for removing soil or decomposed rock overlying jointed rock, beneath both upstream and downstream shells, to expose the joints for treatment, should receive detailed study. If joints are not exposed for treatment and are wide, material filling them may be washed from the joints when the reservoir pool rises, or the joint-filling material may consolidate. In either case, embankment fill may be carried into the joint, which may result in excessive reservoir seepage or possible piping. This consideration applies to both earth and rock-fill dams.

(6) Where faults or wide joints occur in the embankment foundation, they should be dug out, cleaned and backfilled with lean concrete, or otherwise treated as previously discussed, to depths of at least three times their widths. This will provide a structural bridge over the fault or joint-filling materials and will prevent the embankment fill from being lost into the joint or fault. In addition, the space beneath the concrete plug should be grouted at various depths by grout holes drilled at an angle to intersect the space. This type of treatment is obviously required beneath cores of earth and rock-fill dams and also beneath rock-fill shells.

c. Abutment treatment. The principal hazards that exist on rock abutments are due to irregularities in the cleaned surfaces and to cracks or fissures in the rock. Cleaned areas of the abutments should include all surfaces beneath the dam with particular attention given to areas in contact with the core and filters. It is good practice to require both a preliminary and final cleanup of these areas. The purpose of the preliminary cleanup is to facilitate inspection to identify areas that require additional preparation and treatment. Within these areas, all irregularities should be removed or trimmed back to form a reasonably uniform slope on the entire abutment. Overhangs must be eliminated by use of concrete backfill beneath the overhang or by barring and wedging to remove the overhanging rock. Concrete backfill may have to be placed by shotcrete, gunite, or similar methods to fill corners beneath overhangs. Vertical rock surfaces beneath the embankment should be avoided or, if permitted, should not be higher than 5 ft, and benches between vertical surfaces should be of such width as to provide a stepped slope comparable to the uniform slope on adjacent areas. Relatively flat abutments are desirable to avoid possible tension zones and resultant cracking in the embankment, but this may not be economically possible where abutment slopes are steep. In some cases, however, it may be economically possible to flatten near vertical rock abutments so they have a slope of 2 vertical on 1 horizontal or 1 vertical on 1 horizontal, thereby minimizing the possibility of cracking. Flattening of the abutment slope may reduce the effects of rebound cracking (i.e., stress relief cracking) that may have accompanied the development of steep valley walls. The cost of abutment flattening may be offset by reductions in abutment grouting. The cost of foundation and abutment treatment may be large and should be considered when selecting damsites and type of dam.

5-2. Strengthening the Foundation

a. Weak rock. A weak rock foundation requires individual investigation and study, and dams on such foundations usually require flatter slopes. The possibility of artisan pressures developing in stratified rock may require installation of pressure relief wells.

b. Liquefiable soil. Methods for improvement of liquefiable soil foundation conditions include blasting, vibratory probe, vibro-compaction, compaction piles, heavy tamping (dynamic compaction), compaction (displacement) grouting, surcharge/buttress, drains, particulate grouting, chemical grouting, pressure-injected lime, electrokinetic injection, jet grouting, mix-in-place piles and walls, insitu vitrification, and vibro-replacement stone and sand columns (Ledbetter 1985, Hausmann 1990, Moseley 1993).

c. Foundations. Foundations of compressible fine-grained soils can be strengthened by use of wick drains, electroosmotic treatment, and slow construction and/or stage construction to allow time for consolidation to occur. Because of its high cost, electroosmosis has been used (but only rarely) to strengthen foundations. It was used at West Branch Dam (now Michael J. Kirwan Dam), Wayland, Ohio, in 1966, where excessive foundation movements occurred during embankment construction (Fetzer 1967).

5-3. Dewatering the Working Area

a. Trenches. Where cutoff or drainage trenches extend below the water table, a complete dewatering is necessary to prepare properly the foundation and to compact the first lifts of embankment fill. This may also be necessary where materials sensitive to placement water content are placed on embankment foundations having a groundwater level close to the surface. This may occur, for example, in closure sections.

b. Excavation slopes. The contractor should be allowed a choice of excavation slopes and methods of water control subject to approval of the Contracting Officer (but this must not relieve the contractor of his responsibility for satisfactory construction). In establishing payment lines for excavations, such as cutoff or drainage trenches below the water table, it is desirable to specify that slope limits shown are for payment purposes only and are not intended to depict stable excavation slopes. It is also desirable to indicate the need for water control using wellpoints, deep wells, sheeted sumps, slurry trench barriers, etc. Water control measures such as deep wells or other methods may have to be extended into rock to lower the groundwater level in rock foundations. If the groundwater is to be lowered to a required depth below the base of the excavation, this requirement shall be stated in the specifications. Dewatering and groundwater control are discussed in detail in TM 5-818-5.